

## **Task**

Developing NDE Techniques for Large Cryogenic Tanks

## **Center Point of Contact**

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## **Objective**

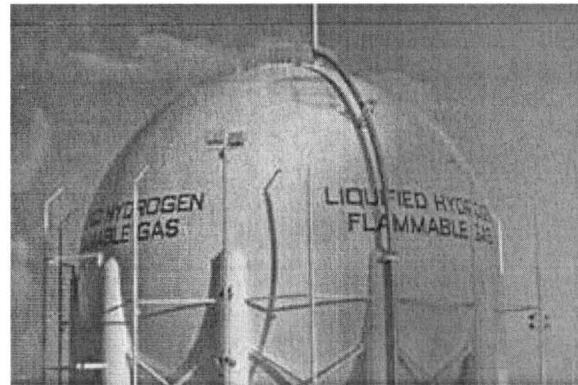
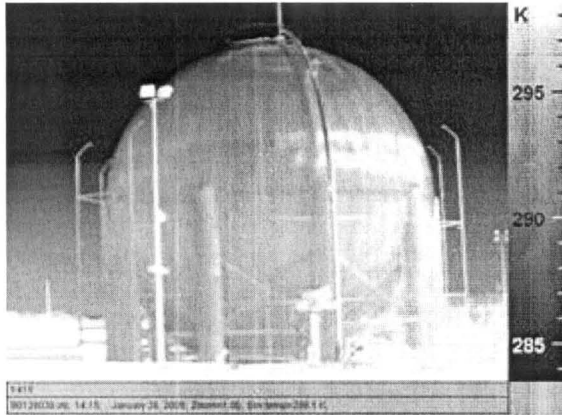
- Develop NDE techniques to detect problems early in existing large cryogenic storage tanks so that corrective actions can be scheduled
- Explore the use of NDE techniques as acceptance testing methods to apply when new tanks are constructed for future launch programs.

## **Background**

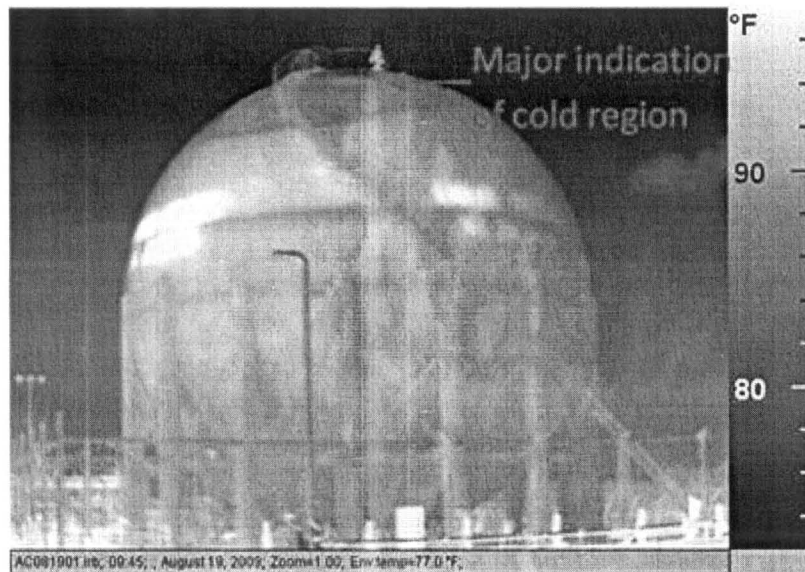
The Shuttle Program requires very large cryogenic ground storage tanks in which to store liquid oxygen and hydrogen. The existing Pads A and B Launch Complex-39 tanks, which will be passed onto future launch programs, are 45 years old and have received minimal refurbishment and only external inspections over the years. The majority of the structure is inaccessible without a full system drain of cryogenic liquid and granular insulation in the annular region. It was previously thought that there was a limit to the number of temperature cycles that the tanks could handle due to possible insulation compaction before undergoing a costly and time consuming complete overhaul; therefore the tanks were not drained and performance issues with these tanks, specifically the Pad B liquid hydrogen tank, were accepted. There is a need and an opportunity, as the Shuttle program ends and work to upgrade the launch pads progresses, to develop innovative non-destructive evaluation (NDE) techniques to analyze the current tanks. Techniques are desired that can aid in determining the extent of refurbishment required to keep the tanks in service for another 20+ years. A nondestructive technique would also be a significant aid in acceptance testing of new and refurbished tanks, saving significant time and money, if corrective actions can be taken before cryogen is introduced to the systems.

## **Approach**

- Time series thermal images of two sides of the Pad B liquid hydrogen tank have been taken over multiple days to demonstrate the effects of environmental conditions to the solar heating of the tank and therefore the effectiveness of thermal imaging. The two pictures below show the Pad B LH2 tank in the infrared and in the visible. Both images show an anomalous cold spot at the top of the tank, a location where it was later confirmed that a void in the insulation existed. In the visible image this spot is dark due to growth of mold over an area that stays wet from condensation. In the IR image it is cold around the edges, but warmer at center due to the presence of the mold. Also, in the IR image the internal support structures are visible, due to solar heating. As the sun rises the tank warms, the plate steel heating first except where underlying steel beams increase the heat capacity, causing a delay in the heating process.



- A mathematical model was developed to explain the effect of then assumed insulation void which seemed to verify the existence of the void based on detailed analysis of liquid level records over many years. This insulation void was confirmed during inspections of the annular region of the tank in 2010.
- Imaging of the Pad A liquid oxygen and liquid hydrogen tanks and the Pad B liquid oxygen tank has shown that there are no obvious structural issues but there is a likely Perlite void in the upper space of the Pad A liquid oxygen tank which is consistent with analysis of liquid level (boil-off data). The picture below shows the cold spot at the top of this tank, consistent with a possible perlite void caused by settling/compaction of this powder-like insulation material.



- Imaging of the Pad B liquid hydrogen tank continued through 2010 as the tank was drained of liquid hydrogen and warmed to ambient conditions. Imaging of the tank through this process indicates that thermal imaging may be a viable tool for determining the existence of insulation voids prior to cryogenic liquid being introduced into the tanks. Imaging will continue now that the void has been filled with additional insulation in order to compare images with and without an insulation void under ambient conditions.

- Investigation is currently being performed to determine if a non-invasive spectroscopic technique can be used to determine the insulation density in the annular region of the storage tanks through the outer steel shell. It is hoped that this technique can be used to determine the existence of insulation voids and well as possible regions of compacted insulation.

### **Benefits/Payoff/Products**

- The primary benefit of this work has been in helping the Constellation Program decide the extent of the refurbishment to perform on the Pad B liquid hydrogen tank. The technical expertise developed under this project, along with the mathematical models, allowed us to address numerous questions that arose during the evaluation of the tank. At present insulation has been added to the Pad B liquid hydrogen tank to fill the annular region while refurbishment of components and areas of corrosion on the exterior of the tank is ongoing. Our knowledge and the NDE techniques developed under this NNWG project will continue to be used as we at KSC complete the refurbishment of this tank and analyze the refurbishment needs of the other three large storage tanks once the Shuttle program is complete.
- An annual report was prepared and distributed to KSC and Stennis Cryogenic communities and will be posted on the PBMA NNWG website.

### **Status/Recent Accomplishments**

- Develop a Class 1 Div 2 displacement sensor to be used during LH2 loading to determine if stress is transferred to the outer sphere due to Perlite compaction.
- Determine the effectiveness of thermal imaging for the evaluation and acceptance of new cryogenic storage tanks before cryogenics are introduced.
- Support Engineering Review Boards and Program Review Boards at KSC to make decisions regarding the refurbishment of the Pad B LH2 tank.
- Coordinate with Stennis Space Center to identify issues they may be having with Cryogenic vessels amenable to NDE innovations.
- Investigate a non-invasive technique for determining insulation density through the steel walls of the storage vessels.